Journal of Environmental Protection, 2014, 5, 530-550
Published Online May 2014 in SciRes. http://www.scirp.org/journal/jep
http://dx.doi.org/10.4236/jep.2014.56056

New Model for Environmental Impact Assessment of Tunneling Projects

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Received 26 December 2013; revised 25 January 2014; accepted 21 February 2014

Abstract

Designers of infrastructure are aware that the government, owners and users become more and more concerned about negative environmental impacts of tunnels, so environmental assessment of tunnels are becoming an issue in the process of tunnel design. In this study, to assess tunnels in construction and operation phases, the matrix method, through which the "Impacting Factors" and "Environmental Components" are determined, is also outlined. The affected environment was divided into thirteen components, such as Ecology, Surface water, Air quality, etc. In this paper, matrix method was applied to evaluate the impact of tunneling in three typical tunnels and compare them with standard diagrams of Environmental Components that were derived and introduced. These tunnels were: Urban Utility tunnel in Tehran, Eurasia tunnel in Istanbul and Tsuen Wan drainage tunnel in Hong Kong. Based on the acquired results, the present paper finally concluded that among three cases, Tsuen Wan drainage tunnel affects the environment in construction phase more than others, while Eurasia tunnel effects on air quality are more significant in operation phase.

Keywords

Environmental Impact Assessment, Tunneling, Matrix Method, Urban Utility Tunnel in Tehran, Eurasia Tunnel in Istanbul, Tsuen Wan Drainage Tunnel in Hong Kong

1. Introduction

The concept of Environmental Impact Assessment (EIA) refers to the examination, analysis and assessment of planned activities with a view to ensuring their environmental soundness and sustainable development. It is said

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How to cite this paper: Namin, F.S., Ghafari, H. and Dianati, A. (2014) New Model for Environmental Impact Assessment of Tunneling Projects. *Journal of Environmental Protection*, **5**, 530-550. http://dx.doi.org/10.4236/jep.2014.56056

to be a valuable means of promoting the integration of environmental and natural resource issues into planning and program implementation [1].

Since its introduction in the United States in the late 1960s, EIA has been adopted and implemented by many developed and developing countries [2]-[13]. Numerous EIA methodologies have been developed such as interaction matrices, networks, weighting-scaling (or -ranking or -rating) checklists [14], multicriteria/multiattribute decision analysis (MCDA/MADA) [15]-[30], input-output analysis [30], life cycle assessment (LCA) [32]-[34], AHP or fuzzy AHP [35]-[37], fuzzy sets approaches [38]-[41], Rapid Impact Assessment Matrix (RIAM) [41]-[44], and data envelopment analysis (DEA) [46].

The purpose of incorporating EIA approaches has been described as subjecting a proposed action to an examination of what the possible environmental impacts of that action would be and to find ways to mitigate any negative long-term impacts [47]. Therefore, the main aims of the environmental assessment could be summarized as follows [48]:

Prevention of the destructive effects, resulting from mining activities.

Consideration of the environmental laws and standards in all the stages of mine life.

Establishment of enough knowledge about the importance of the environmental issues in project management.

Estimation of the required costs for the prevention of environmental adverse effects.

Qualitative and quantitative assessment of the effective parameters of mining units on environment, and finally, making some suggestions for lessening of the natural resource pollution.

The increasing demand for raw materials and infrastructure of human society, cities and transportation systems run fast in these parts; it requires more underground excavations. Underground excavation in the world between 1980 and 1990 was the annual average of 16.2 × 108 cubes meter and appear to be continuing this process exponentially [49]. Annual production of Coal in the world is about 4×10^9 tons. If 60 percent of this value is extracted from underground mines and the length of tunnels needed to extract 10000 tons of coal is 12 to 14 meters, only in coal mines 19,200 to 22,400 kilometers per year, tunnel is required [50].

Tunneling in Iran has risen dramatically in recent years and large projects in the field of tunnel construction are done.

Designers of infrastructure are aware that the government, owners and users become more and more concerned about negative environmental impacts of tunnels, so environmental aspects of tunnels are becoming an issue in the process of tunnel design of increasing importance [51].

Therefore, in construction, maintenance and operation of underground systems, all favorable or adverse social-economic effects and environmental impacts should be identified and considered.

Generally, tunnels can be divided into three kinds, transportation tunnels, industrial tunnels and mining tunnels:

1) Transportation tunnels: including rail tunnels (length less than 3 km), road tunnels, subway tunnels, sea tunnels and sidewalk tunnels.
2) Industrial tunnels: including water transfer tunnels (fewer cross section and length of less than 40 km), sewage tunnels and tunnels to ware houses, bunkers, nuclear waste disposal areas.
3) Mining tunnels: including opening tunnels exploration tunnels, extraction tunnels, service tunnels, drainage tunnels and inspection tunnels.

Given the variety of tunnels and their different applications and unique structural features of each tunnel, in overall we can identify and evaluate similar environmental impact resulting from the construction and operation of tunnels. Destruction of the landscape and the physical condition of tunnel's intake and outfall, changing direction and groundwater pollution, interference with hydrogeology conditions, destruction of forests, noise pollution, vibrations caused by the blast and air blast, dust emission, impairment to health of workers, high risk of adverse events occurring during tunnel construction, the difficulty of access and transport victims of accidents in tunnels, increase in vehicle traffic in the tunnel excavation, fly rocks at the outfall of the tunnel and subsidence are the most important environmental impacts of tunneling [52].

Some studies have been conducted so far on the devastating effects of tunneling on the environment and the ways to assess them. Leendert A. van Geldermalsen [51] used the framework of the DARTS (Durable and Reliable Tunnel Structures) to select the economic and optimal tunnel construction and dealt with the environmental aspects of decision-making in the design process. Robati and Atabi [53], by using integrated matrix (Leopold-Saratoga), evaluated environmental impacts of the urban utility tunnel construction. Some other researchers that have done related studies are: [54]-[58]. In due course, Blodgett and Kuipers studied the effect of mining on both surface and groundwater reservoirs. By examining the clay-rich mine tailings, Krekeler *et al.* [59] explored the environmental and economic impact of the phosphate ore processing. According to [60], in environmental management, socio-economic issues in the form of improving public perceptions are just as important as scientific investigations. Hamilton [61] used a database to identify the unusual and unexpected concentrations of elements in the mine tailings. Hancock and Turley [62] used numerical modeling to design a proposed waste-rock dump. Assessment of the amount of pollutants in soil drainage can be made by estimating the amount of drainage passing through the soil bottom during a given time period. This estimation can be a stochastic model [63]. Antunes *et al.* [64] performed an environmental risk assessment by categorizing soils based on their toxicity profiles. The above investigations are very useful, though, often take into account limited aspects of environmental impact. Except to the Folchi technique [65], existing evaluation methods are limited in scope, with just one or two aspects of environmental impacts of mining and ore processed. Folchi method evaluates many environmental impacts of mining operations *i.e.* ground vibration, fly rock, air blast [66], water/air pollution, etc. simultaneously. Collection and monitoring of data are also simple for this method. M. mirmohammadi *et al.* [67] suggested an algorithm that attempts to develop the Folchi matrix method for assessment of the effects of mining units, including underground mines and mineral processing plants. Furthermore, M. mirmohammadi *et al.* [68] suggested another algorithm for assessment of the effects of mining units, including surface mines and mineral processing plants.

Given that most of the methods mentioned are used for environmental assessment of mining units, this paper attempts to use the proposed mirmohammadi algorithm [67] [68] for environmental assessment of tunnels in both construction and operation phases. Then, assuming allowed standard values, typical graphs of tunneling activities obtained and this algorithm applies on three tunnels *i.e.*, urban utility tunnel in Tehran, Eurasia tunnel in Istanbul and Tsuen Wan drainage tunnel in Hong Kong, to compare with standard diagrams.

Selection criteria for these tunnels are availability of environmental assessment reports and existence of necessary information for this model. In cases where enough data do not exist, or they cannot be initialized by the algorithm, standard values are used assuming that the environmental condition in this impacting factors satisfies the standards.

2. Materials and Methods

2.1. The Environmental Impact of Tunneling Operations

Table 1 shows an inventory of all the environmental aspects that can play a role during the realization and exploitation phase of a tunnel.

Creating new paths to access the tunnel face, destroy landscape and existing environmental conditions. Construction of road access is an inevitable intervention in the environment that causes significant impacts by removal of trees, earth excavation and embankment. In general, geomorphologic alteration, changes in working surface, ground water level, potential increase of erosion phenomena, destruction natural inhabitants of animals and plants, increase of dust concentration in the atmosphere and decrease in prices of surrounding areas are adverse environmental effects of the access and exit roads.

The main sources of noise in the tunnel during construction include:

- Noise from blasting for excavation tunnels
- Noise from drilling machines, instruments, loading, etc.
- Noise from traffic and transportation around the tunnel
- Noise from loading and haulage
- Noise from fans for tunnel ventilation

One of the most significant undesirable impacts on the environment is disposing of excavated materials during the tunnel excavation. Disposal of waste materials in the construction of the tunnel is a type of effects that can create detrimental effects on environment such as water pollution, soil contamination and pollution of natural ecosystems.

Tunneling operations can change the direction of groundwater flow and cause environmental impacts on soil chemistry. Water flows in the springs and where the water naturally comes out, may be decreased due to groundwater discharge from drainage of surrounding grounds of the tunnel site.

Disposal of waste water remained from tunneling also have undesirable impacts on the environment. Because as regard to the possibility of contamination of these waters and emerging at surface can create irreversible problems for living things.

Table 1. Overview of all the environmental aspects that play a role in tunnel design [51].

Environmental issues (general)	Environmental effects/aspects
Emissions	Air pollution (traffic & explosives)
	Smell
	Wastewater (rain, drainage, groundwater, drilling)
	Pollution of ground & groundwater
	Pollution of surface water
	Pollution of excavated material (debris/muck/dredged material)
Environmental quality	Quality of soil & groundwater
	Air quality
	Surface water quality
	Groundwater level
	Soil (in) stability
Materials	Primary building materials
	Secondary building materials
	Renewable materials
	Reusable excavated material
	(Chemical) Products
	(Dangerous) Waste material
Energy	Production of building materials
	Transport of building materials
	Construction equipment
	Installations
	Traffic
Living conditions	Noise
	Vibrations
	Dust
Cultural quality	Visual design & landscape values
	Archaeological, palaeolontological and geomorphological values
	Historical and cultural heritage
	Demolition of real estate & other manmade structures
Habitat	Degradation of habitat
	Fragmentation of habitat
	Disturbance of fauna

Furthermore, creating employment opportunities for local people and migrants increase in population density, economic growth and expansion, revenue from taxes, state salaries and easier access to the infrastructural facilities are benefits of tunnel construction [52].

2.2. The Algorithm for Environmental Impact Assessment of Tunnels

Environmental assessments are often performed by using matrix methods in which one dimension of the matrix is "Impacting Factors" (IFs) and the other one is the "Environmental Components" (ECs) which are affected by IFs. In the proposed mirmohammadi algorithm for tunnel's method, the affected environment is broken down into several components, such as public health and safety, social relationship, air and water quality, etc. It is necessary to introduce destructively and usefully effective parameters prior to environment assessment. To evaluate the effects of tunneling activities including construction and operation phases, twenty overall factors are introduced as "Impacting Factor", their definition and magnitude are listed in (**Table 2**).

For each of twenty above parameters, a table containing several scenarios is defined according to which the magnitude of each parameter can be determined. For severely destructive parameters, the factor mark is between 0 and 10, that zero means it is ineffective, and 10 shows the most critical condition. Some factors like economical and cultural issues have a mark between -10 and 10. The negative sign shows their positive effect.

In the next stage, issues which influence of a tunneling activity on them is probable are defined as Environmental Components (**Table 3**).

Environmental Components are parts of environment, which are influenced by Impacting Factors.

In this method, first, amount of each Impacting Factor in **Table 1** should be determined. The next step in this algorithm is to designate the influence of "Impacting Factors" on "Environmental Components." Effect of each IF on each EC is expressed by four statements, Nil, Minimum, Medium, and Maximum. As a result, a table assembled, which shows the effect level of each factor on Components (**Table 4** and **Table 5**). Each factor changes the condition of each Environmental Component before tunneling, in respect of a coefficient. Assuming the sum of these coefficients equals to 10, and the maximum effect is twice the medium, and the effect of a medium is twice the minimum. Hence, influence of "Impacting Factors" on each "Environmental Component" could be written as follows:

$$\left[C^c\right] = \left[F^c\right] * \left[M^c\right] \quad (1)$$

$$\left[C^o\right] = \left[F^o\right] \left[M^o\right] \quad (2)$$

In the equations above, c and o show tunneling construction and operation phases, respectively, and C is a 1 × 13 matrices whose elements represent the Environmental Components; also, F is a 1 × 20 matrices whose elements represent the Impacting Factors values. Finally, the components of matrix C are depicted in a column graph which describes the amount of effect on each Environmental Component separately. To mark each scenario, the Iranian standards [69] [70] have been used; furthermore, international standards and guidelines [e.g. United Nations, 1992, 2002] and [World Bank Environment Health and safety guidelines] have been used where Iranian ones doesn't exist. It should be mentioned that Iranian standards are mainly based on international standards with little modifications according to domestic situation (**Figure 1**).

3. Site Descriptions

This article applies the method in three tunnels namely Urban Utility tunnel in Tehran; Eurasia road tunnel in Istanbul and Tsuen Wan drainage tunnel in Hong Kong.

3.1. Urban Utility Tunnel District 22 of Tehran

District 22 of municipality of Tehran is located in the northwest region of Tehran Province and in the downstream Kan and Vardavard River basins (**Figure 2**). This area is limited in the north with the Alborz Mountains, in the East with Kan River surrounding, in the south with the Tehran-Karaj freeway and in the West with Vardavard forests and is in contact with districts 5 and 21 of Tehran. Northern boundary of the district 22 of Tehran has been developed from extreme southern domains of Alborz as high as 1800 meters. Construction of the tunnel's main part with 5 km length and parallel to Hemmat highway has been accomplished. In some places, its diameter is such that service vehicles can travel to provide and maintain equipment easily.

The tunnel is constructed with a cost of over 50 billion Rials in the North West of Tehran. Drinking water pipes, raw water pipes (non-drinkable and firefighting), MV and LV power cables, telecommunication cables and optical fibers, using for traffic lights in the streets, radio and television cable systems and other unpredicted cases are common use of this tunnel.

Table 2. The extent of each impacting factor value.

Impacting Factors	**Definition**	**Magnitude**
1. Changing the usage of the area	The usage of the lands before tunneling activities	0 - 10
2. Exposition of the tunneling area	The view and visibility of the tunneling area.	0 - 10
3. Interference with surface water	The relationship between tunneling activities and surface water.	0 - 10
4. Interference with underground water	The relationship between tunneling activities and underground water table.	0 - 10
5. Waste waters	Waste water discharge area of the tunnel.	0 - 10
6. Increase in the traffic of the area	Influence of tunneling on the traffic situation of the area.	0 - 10
7. Dust emission	Dust emission in each part of tunnel. 1- Drilling machines 2- Explosion 3- Loading 4- Movement of the tracks on the road (from tunnel to dump). 5- The dust produced by wind from the waste dumps.	0 - 10
8. Toxic gas emission	Concentration of pollutants in tunnel air (ppm)	0 - 10
9. Noise pollution	-The noise level at the work environment caused by devices and machines in qualitative and quantitative form. -Noise level caused by firing.	0 - 10
10. Land vibration	Intensity of underground vibration in the main underground facilities installations, refreshing place of the workers or the cross point of the shafts with the tunnel level (mm/sec). The intensity of vibration on the surface with regard to the distance to the surface facilities.	0 - 10
11. Fly rock	Fly rock caused by blasting	0 - 10
12. Materials existed in the waste dump	The pollution level of the materials which exist in the waste dump.	0 - 10
13. Waste discharge method	Waste discharge method Geological studies of the waste dump, waste dam construction, and prediction of the dam life time. Monitoring and control during the dam operation. Putting signs and fences around the tailing dump and dam.	0 - 10
14. Domestic employment	Domestic employment rate in tunneling site	−10 - 10
15. Population control	Influence of tunneling on the population of the area Population of the tunneling site before and after the tunneling operation. The type of influence of tunneling activities on the change in population.	−10 - 10
16. Social and cultural development	Condition of the social and cultural institutes before and after the tunneling operation, in the fields bellow: Educational, health and help, cultural, and artistic institutes Sport institutes. Amusement, and economical institutes Condition of urban facilities before and after the start of the tunneling operation in the fields bellow: Water facilities, heating facilities, availability of the electricity, access roads, receiving the TV channels, and phone connections.	−10 - 10
17. Instability of the established spaces	Stability condition of the excavation in the tunnel.	0 - 10
18. Subsidence	The subsidence condition in the tunneling area	0 - 10
19. Environmental arrangements	Green space construction, existence of R & D in the tunneling site, taking the environmental ISO, assembling the health, security and environmental manuals. Dust controlling unit, lessening the noise level, Recycling the gangue dam water, refining the industrial and sanitary waste water of the tunneling site.	−10 - 10
20. Light	Illumination (Lux) in the work area.	0 - 10

Table 3. Considered environmental components for the suggested algorithm.

1	Human health and immunity	8	Surface constructions
2	Social issues	9	Underground constructions
3	Surface water	10	Area landscape
4	Underground water	11	Quietness
5	Air quality	12	Economical issues
6	Area usage	13	Soil of the area
7	Ecology		

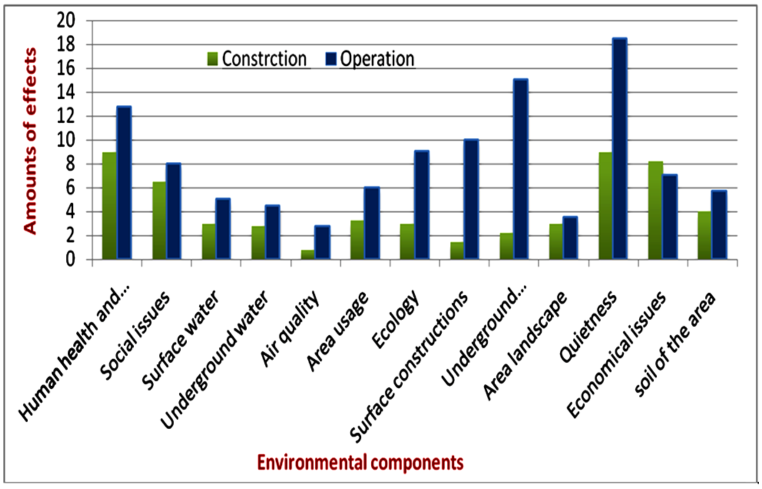

Figure 1. The designed graph for tunnel assessment based on allowed percentage of Environmental Components for an imaginary case study according to Impacting Factors, which satisfy the standards.

Figure 2. Urban utility tunnel district 22 of Tehran.

One of the paramount issues of tunneling in shallow urban areas specially soft grounds is subsidence and its effect on adjacent structures, which will cause landslide and settlement of the surrounding structures. To prevent above cases, stabilization of the soil around the tunnel should be done. Slope for ground leveling preparation for construction of the utility tunnel should be considered, but due to topographic location of the construction site, the natural slope can make intubation and leveling easy [53].

Owing to the fact that some information was not available to determine the magnitude of impacting factors;

Table 4. The weighted values of the effect of each Impacting Factor on each designed environmental component for tunnels in construction phase.

Impacting Factors	Environmental Components												
	Human health and immunity	Social issues	Surface waters	Underground waters	Air quality	Area usage	Ecology	Surface constructions	Underground constructions	Area landscape	Quietness	Economical issues	Soil of the area
Changing the usage of the area	Med	Min	Med	Med	Nil	Max	Min	Nil	Nil	Max	Nil	Max	Max
	0.4	0.34	0.72	0.74	0	1.6	0.38	0	0	1.48	0	0.84	1.72
Exposition of the tunneling area	Nil	Nil	Nil	Nil	Nil	Med	Nil	Nil	Nil	Max	Min	Nil	Nil
	0	0	0	0	0	0.8	0	0	0	1.48	0.83	0	0
Interference with surface water	Max	Nil	Max	Max	Min	Med	Max	Min	Nil	Max	Nil	Min	Max
	0.8	0	1.44	1.48	0.56	0.8	1.52	1.25	0	1.48	0	0.21	1.72
Interference with underground water	Med	Nil	Max	Max	Nil	Min	Max	Nil	Med	Nil	Nil	Min	Min
	0.4	0	1.44	1.48	0	0.4	1.52	0	1.66	0	0	0.21	0/43
Waste waters	Min	Nil	Med	Med	Nil	Min	Max	Nil	Nil	Max	Nil	Nil	Med
	0.2	0	0.72	0.74	0	0.4	1.52	0	0	1.48	0	0	0.86
Increase in the traffic of the area	Max	Max	Nil	Nil	Min	Nil	Min	Nil	Nil	Min	Med	Min	Nil
	0.8	1.36	0	0	0.56	0	0.38	0	0	0.37	1.66	0.21	0
Dust emission	Max	Min	Med	Nil	Max	Nil	Min	Nil	Nil	Nil	Nil	Med	Nil
	0.8	0.34	0.72	0	2.24	0	0.38	0	0	0	0	0.42	0
Toxic pollutants and substances emission to air	Max	Nil	Nil	Min	Max	Nil	Med	Nil	Nil	Nil	Nil	Max	Nil
	0.8	0	0	0.37	2.24	0	0.76	0	0	0	0	0.84	0
Noise pollution	Med	Med	Nil	Nil	Nil	Nil	Min	Nil	Nil	Nil	Max	Min	Nil
	0.4	0.68	0	0	0	0	0.38	0	0	0	3.32	0.21	0
Land vibration	Max	Min	Nil	Nil	Nil	Min	Med	Med	Max	Nil	Nil	Min	Nil
	0.8	0.34	0	0	0	0.4	0.76	2.5	3.32	0	0	0.21	0
Fly rock	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials existed in the waste dump	Max	Med	Max	Max	Med	Med	Med	Nil	Nil	Nil	Nil	Max	Max
	0.8	0.68	1.44	1.48	1.12	0.8	0.76	0	0	0	0	0.84	1.72
Waste discharge method	Max	Med	Max	Med	Med	Max	Med	Nil	Nil	Max	Nil	Max	Max
	0.8	0.68	1.44	0.74	1.12	1.6	0.76	0	0	1.48	0	0.84	1.72
Domestic employment	Nil	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Max	Nil
	0	1.36	0	0	0	0	0	0	0	0	0	0.84	0
Population control	Min	Max	Nil	Nil	Nil	Med	Nil	Nil	Nil	Nil	Min	Max	Nil
	0.2	1.36	0	0	0	0.8	0	0	0	0	0.83	0.84	0
Social and cultural development	Min	Max	Nil	Nil	Nil	Min	Nil	Nil	Nil	Nil	Nil	Med	Nil
	0.2	1.36	0	0	0	0.4	0	0	0	0	0	0.42	0
Instability of the established spaces	Max	Nil	Min	Med	Nil	Nil	Nil	Min	Med	Nil	Nil	Max	Nil
	0.8	0	0.36	0.74	0	0	0	1.25	1.66	0	0	0.84	0
Subsidence	Nil	Med	Min	Med	Nil	Max	Min	Max	Max	Med	Nil	Max	Med
	0	0.68	0.36	0.74	0	1.6	0.38	5	3.32	0.74	0	0.84	0.86
Environmental arrangements	Max	Med	Max	Max	Max	Min	Min	Nil	Nil	Max	Max	Max	Med
	0.8	0.68	1.44	1.48	2.24	0.4	0.38	0	0	1.48	3.32	0.84	0.86
Light	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Med	Nil
	0.8	0	0	0	0	0	0	0	0	0	0	0.42	0

Table 5. The weighted values of the effect of each impacting factor on each designed environmental component for tunnels in operation phase.

Impacting Factors	Environmental Components												
	Human Health and immunity	Social issues	Surface waters	Underground waters	Air quality	Area usage	Ecology	Surface constructions	Underground constructions	Area landscape	Quietness	Economical issues	Soil of the area
Changing the usage of the area	Med	Min	Med	Med	Nil	Max	Min	Nil	Nil	Max	Nil	Max	Max
	0.5	0.45	0.96	0.86	0	2.12	0.59	0	0	2.36	0	1.08	2.68
Exposition of the tunneling area	Nil	Min	Nil	Nil	Nil	Med	Nil	Nil	Nil	Max	Nil	Min	Nil
	0	0.45	0	0	0	1.06	0	0	0	2.36	0	0.27	0
Interference with surface water	Max	Nil	Max	Max	Min	Med	Max	Min	Nil	Med	Nil	Min	Max
	1.00	0	1.92	1.72	0.71	1.06	2.36	1.43	0	1.18	0	0.27	2.68
Interference with underground water	Med	Nil	Max	Max	Nil	Min	Max	Nil	Min	Nil	Nil	Min	Min
	0.5	0	1.92	1.72	0	0.53	2.36	0	1.11	0	0	0.27	0.67
Waste waters	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase in the traffic of the area	Max	Max	Nil	Nil	Min	Nil	Min	Nil	Nil	Min	Med	Min	Nil
	1.00	1.8	0	0	0.71	0	0.59	0	0	0.59	1.82	0.27	0
Dust emission	Min	Nil	Min	Nil	Max	Nil	Nil	Nil	Nil	Nil	Nil	Min	Nil
	0.25	0	0.48	0	2.84	0	0	0	0	0	0	0.27	0
Toxic pollutants and substances emission to air	Max	Nil	Nil	Min	Max	Nil	Med	Nil	Nil	Nil	Nil	Max	Nil
	1.00	0	0	0.43	2.84	0	1.18	0	0	0	0	1.08	0
Noise pollution	Min	Min	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Max	Min	Nil
	0.25	0.45	0	0	0	0	0	0	0	0	3.64	0.27	0
Land vibration	Max	Min	Nil	Nil	Nil	Min	Min	Min	Med	Nil	Nil	Min	Nil
	1.00	0.45	0	0	0	0.53	0.59	1.43	2.22	0	0	0.27	0
Fly rock	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials existed in the waste dump	Max	Min	Max	Max	Nil	Min	Med	Nil	Nil	Nil	Nil	Med	Med
	1.00	0.45	1.92	1.72	0	0.53	1.18	0	0	0	0	0.54	1.34
Waste discharge method	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic employment	Nil	Min	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Med	Nil
	0	0.45	0	0	0	0	0	0	0	0	0	0.54	0
Population control	Min	Max	Nil	Nil	Nil	Med	Nil	Nil	Nil	Nil	Min	Max	Nil
	0.25	1.8	0	0	0	1.06	0	0	0	0	0.91	1.08	0
Social and cultural development	Min	Max	Nil	Nil	Nil	Min	Nil	Nil	Nil	Nil	Nil	Med	Nil
	0.25	1.8	0	0	0	0.53	0	0	0	0	0	0.54	0
Instability of the established spaces	Max	Nil	Min	Med	Nil	Nil	Nil	Min	Med	Nil	Nil	Med	Nil
	1.00	0	0.48	0.86	0	0	0	1.43	2.22	0	0	0.54	0
Subsidence	Nil	Med	Min	Med	Nil	Max	Min	Max	Max	Med	Nil	Max	Med
	0	0.9	0.48	0.86	0	2.12	0.59	5.72	4.44	1.18	0	1.08	1.34
Environmental arrangements	Max	Med	Max	Max	Max	Min	Min	Nil	Nil	Max	Max	Max	Med
	1.00	0.9	1.92	1.72	2.84	0.53	0.59	0	0	2.36	3.64	1.08	1.34
Light	Max	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Med	Nil
	1.00	0	0	0	0	0	0	0	0	0	0	0.54	0

the standard values were used. That's why magnitude of standard environmental arrangements, light and noise pollution were taken into account.

3.2. Eurasia Road Tunnel

This new road tunnel proposed to be constructed in the Istanbul Metropolis, Turkey. The Eurasia Tunnel Project comprises a 5.4 km road tunnel beneath the Bosphorus Strait, between the European and Asian shores of Istanbul, together with the widening of a total of 9.2 km of existing roads on both sides to form the approaches to the tunnel. The Project location is shown in **Figure 3**.

Initial predictions indicate that journey times from Europe to Asia will reduce from up to 100 minutes today to as little as 15 minutes with the Project. Construction of the Project will take approximately 55 months and is expected to open in 2015.

This should provide substantial economic benefits in improved accessibility, reduced journey times and improved reliability, and lead to an overall reduction in fuel consumption, greenhouse gas and other emissions, and noise.

The Project comprises the upgrading of two existing roads, on the European and Asian sides of Istanbul and construction of a double-deck tunnel under the southern end of the Bosphorus. The length of the Project is approximately 14.6 km, and it falls into three main sections.

- Part 1, on the European side: widening of Kennedy Caddesi from Kazliçesme to the Bosphorus, from 3 × 2 lanes to 2 × 4 lanes, over a length of approximately 5.4 km, including 5 u-turn underpasses and seven pedestrian footbridges.
- Part 2, under the Bosphorus: construction of a double-deck tunnel with two lanes at each level over a length of 5.4 km, together with a toll plaza and operations building at the western entrance, and ventilation shafts and electrical buildings at both ends.
- Part 3, on the Asian side: widening the existing D100 road leading to the Ankara-Istanbul State Highway at Göztepe, from 2 × 3 and 2 × 4 lanes to 2 × 4 and 2 × 5 lanes, over a length of approximately 3.8 km, including two interchanges, one underpass, one overpass and three pedestrian footbridges [71].

Figure 4 shows that depth of the tunnel at the highest point from the seafloor is 61 meters; On the other hand, in the most profound it is 106.4 meters.

Standard values were used where some information was not available to determine the magnitude of impacting factors; therefore, standard values were used to quantify Social and cultural development, noise pollution and light.

3.3. Tsuen Wan Drainage Tunnel

The Drainage Services Department (DSD) proposed to construct a tunnel with internal diameter of 6.5 m and length of 5.13 km in order to alleviate the flooding risk in Tsuen Wan and Kwai Chung. Construction of the tun-

Figure 3. Eurasia road tunnel location.

nel, outfall and intake structures are planned to commence in mid 2007 for completion by late 2011.

The tunnel's section crosses from intersection of ShingMun and Wo Yi Hop Roads and discharges to south of YauKom Tau underneath Castle Peak Road as shown in **Figure 5**.

The proposed drainage improvement works to comprise a tunnel and associated intakes and outfall structures. The scope of construction works for the tunnel development comprises:

- 5.13 km drainage tunnel system between Kwai Chung and YauKom Tau (reduced from 5.35km during preliminary design);
- Provision of three Intake locations:
- Intake I-1: Kwai Chung, next to the junction of Wo Yip Hop Road and ShingMun Road;
- Intake I-2: At Lo Wai, next to Lo Wai Road;
- Intake I-3: At Tso Kung Tam, about 350m off Route Twist.
- Provision of Outfall O-1: YauKom Tau, underneath the existing Castle Peak Road.

The main tunnel will be constructed using a Tunnel Boring Machine (TBM). The direction of a drive of the TBM excavation will be from outfall O-1 to Intake I-1. Other than the main tunnel, there are other ancillary underground structures, including man access vertical shaft and storm water drop shaft which need to be constructed [72].

Furthermore, due to incomplete data standard magnitude of the Social and cultural development, population control, domestic employment, noise pollution and light, were considered.

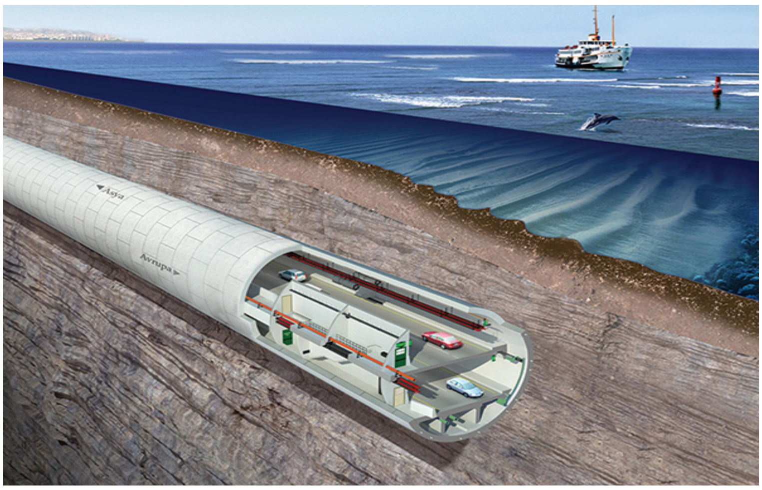

Figure 4. Depth of Eurasia Tunnel from the seafloor.

Figure 5. Tsuen Wan drainage tunnel location.

4. Results

In the present research, the environmental data related to the above three case studies were derived from former environmental reports and studies. Environmental impact research [53] and EIA reports [71] [72] respectively were used to derive information of Urban Utility tunnel, Eurasia road tunnel and Tsuen Wan drainage tunnel. Then using modification Mirmohammadi algorithm [67] [68] each tunnel activity, which affect the environment in both construction and operation phases were evaluated. Further, using the magnitude ranges defined in (Table 2), each impacting factor of the proposed tunneling activity was assessed (**Table 6**). Final scoring for each environmental component can be acquired by multiplying (**Table 4** and **Table 5**) into (**Table 6**). For each case study, the overall effect on each environmental component is calculated by summing the weighted magnitudes of all impacting factors (**Tables 7-9**). This method indicates that specific aspects of environmental impact can be quantified.

The most affected environmental components for Urban Utility tunnel in construction phase are quietness, area landscape and area usage with score values of 25, 19.75 and 16.5, and in operation phase are quietness and human health and immunity with both score values of 9.5, respectively. In the Eurasia road tunnel, environmental components of area usage, area landscape and ecology had scored values of 15.75, 14.5 and 13.25 in construction phase and air quality; economical issues and ecology had scored values of 24.25, 15 and 14.5 in operation phase, respectively. The most affected environmental components in the Tsuen Wan tunnel are area landscape, ecology and soil of the area with scores of 34.5, 28.25 and 21.5 in construction phase, and human health and immunity and economical issues with both scores of 6 in operation phase, respectively (**Figure 6** and **Figure 7**).

5. Discussion

Compare all the above cases with standard values obtained for each environmental component indicates that effects of urban utility tunnel construction in congested city Tehran on area landscape, area usage, soil of the area and quietness exceeded from standard values. The impact on air quality, groundwater and the surface is slightly higher than standard, too. In operation phase this tunnel has no significant impact on the environmental components while social issues show an exceedance from the standard amount (**Figure 7**).

Figure 6 shows in construction phase, Tsuen Wan tunnel has the highest impact on its surrounding environment because it is located in densely populated city of Hong Kong on the other hand, it is in direct contact with ground water, surface water and the sea. This is why the effect of this tunnel on the landscape, ecology, area

Table 6. Rating of environmental parameters in the case study of tunnels.

Impacting Factors	Changing the usage of the area	Exposition of the tunneling area	Interference with surface waste	Interference with underground water	Waste waters	Increase in the traffic of the area	Dust emission	Toxic pollutants to air	Noise pollution	Land vibration	Fly rock	Materials existed in the waste dump	Waste discharge method	Domestic employment	Population control	Social and cultural development	Instability of the established spaces	Subsidence	Environmental arrangements	Light
Standard scenarios	1*	0	0	1	0	1	0	0	5	4	1	1	1	0	0	0	0	0	0	5
	1**	0	0	0	0	1	0	0	2	1	0	1	0	5	0	0	0	0	0	5
Urban Utility Tunnel	1	8	0	1	0	1	0	0	5	1	1	1	4	-5	0	1	0	0	0	5
	1	0	0	0	0	1	0	0	2	1	0	1	0	5	0	1	0	0	0	5
Eurasia Road Tunnel	1.5	10	1	4	1	1	0	1	5	1	1	1	1	-5	2	0	0	0	-5	5
	1.5	0	0	0	0	2	0	10	2	1	0	1	1	0	0	0	0	0	-2	5
Tsuen Wan Drainage Tunnel	1	8	6	0	10	1	0	0	5	1	1	1	1	0	2	0	0	0	-3	5
	1	0	0	0	0	1	0	0	2	0	0	1	1	5	0	0	0	0	-2	5

*For each case study the upper value is for Construction phase. **The under value is for Operation phase.

Table 7. Final scoring for each environmental component in Urban Utility Tunnel District 22 of Tehran in both construction and operation phases.

Impacting Factors	Environmental Components												
	Human Health and immunity	Social issues	Surface waters	Underground waters	Air quality	Are usage	Ecology	Surface constructions	Underground constructions	Area landscape	Quietness	Economical issues	Soil of the area
Changing the usage of the area	0.4^{*}	0.34	0.72	0.74	0	1.6	0.38	0	0	1.48	0	0.84	1.72
	0.4^{**}	0.34	0.72	0.74	0	1.6	0.38	0	0	1.48	0	0.84	1.72
Exposition of the tunneling area	0	0	0	0	0	6.4	0	0	0	11.84	6.64	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Interference with surface water	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Interference with underground water	0.4	0	1.44	1.48	0	0.4	1.52	0	1.66	0	0	0.21	0.43
	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste waters	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase in the traffic of the area	0.8	1.36	0	0	0.56	0	0.38	0	0	0.37	1.66	0.21	0
	1.0	1.8	0	0	0.71	0	0.59	0	0	0.59	1.82	0.27	0
Dust emission	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Toxic pollutants and substances emission to air	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise pollution	2.0	3.4	0	0	0	0	1.9	0	0	0	16.6	1.05	0
	0.5	0.9	0	0	0	0	0	0	0	0	7.28	0.54	0
Land vibration	0.8	0.34	0	0	0	0.4	0.76	2.5	3.32	0	0	0.21	0
	1.0	0.45	0	0	0	0.53	0.59	1.43	2.22	0	0	0.27	0
Fly rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials existed in the waste dump	0.8	0.68	1.44	1.48	1.12	0.8	0.76	0	0	0	0	0.84	1.72
	1.0	0.45	1.92	1.72	0	0.53	1.18	0	0	0	0	0.54	1.34
Waste discharge method	3.2	2.72	5.76	2.96	4.48	6.4	3.04	0	0	5.92	0	3.36	6.88
	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic employment	0	-6.8	0	0	0	0	0	0	0	0	0	-3.36	0
	0	2.25	0	0	0	0	0	0	0	0	0	2.7	0
Population control	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.2	1.36	0	0	0	0.4	0	0	0	0	0	0.42	0
	0.25	1.8	0	0	0	0.53	0	0	0	0	0	0.54	0

Continued

Instability of the established spaces	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidence	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental arrangements	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Light	4.0	0	0	0	0	0	0	0	0	0	0	2.1	0
	5.0	0	0	0	0	0	0	0	0	0	0	2.7	0
Total	12.75	3.5	9.5	6.75	6.25	16.5	8.75	2.5	5	19.75	25	6	10.75
	9.25	8	2.75	2.5	0.75	3.25	2.75	1.5	2.25	2.25	9.25	8.5	3.25

*For each Impacting Factor the upper value is for Construction phase. **The under value is for Operation phase

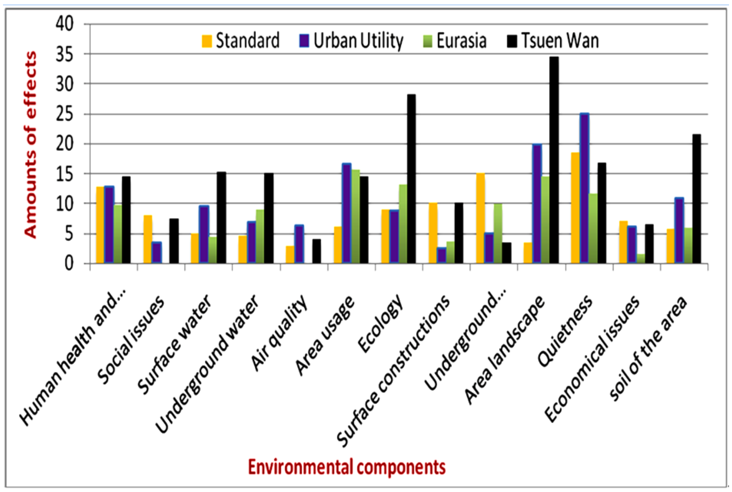

Figure 6. Comparisons between the overall effects on each environmental component related to each tunnel in construction phase.

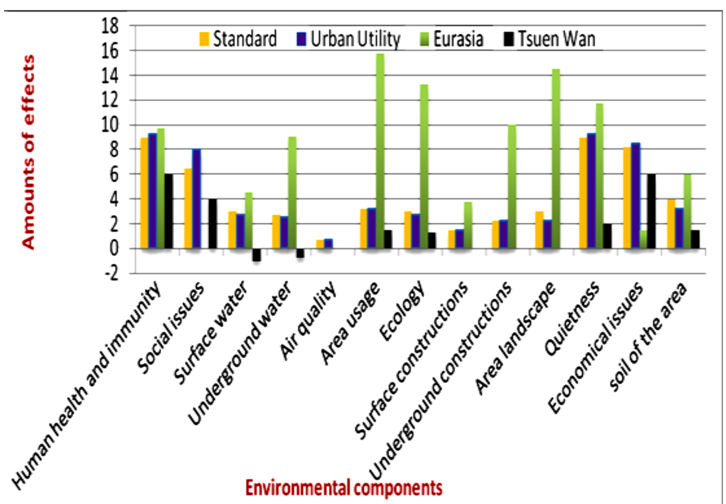

Figure 7. Comparisons between the overall effects on each environmental component related to each tunnel in operation phase.

Table 8. Final scoring for each environmental component in Eurasia Road Tunnel of Istanbul in both construction and operation phases.

Impacting Factors	**Environmental Components**												
	Human health and immunity	Social issues	Surface waters	Underground waters	Air quality	Area usage	Ecology	Surface constructions	Underground constructions	Area landscape	Quietness	Economical issues	Soil of the area
Changing the usage of the area	0.6^{*}	0.51	0.72	1.08	0	2.4	0.57	0	0	2.22	0	1.26	2.58
	0.75^{**}	0.68	1.44	1.29	0	3.18	0.88	0	0	3.54	0	1.62	4.02
Exposition of the tunneling area	0	0	0	0	0	8	0	0	0	14.8	8.3	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Interference with surface water	0.8	0	1.44	1.48	0.56	0.8	1.52	1.25	0	1.48	0	0.21	1.72
	0	0	0	0	0	0	0	0	0	0	0	0	0
Interference with underground water	1.6	0	5.76	5.92	0	1.6	6.08	0	6.64	0	0	0.84	1.72
	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste waters	0.2	0	0.72	0.74	0	0.4	1.52	0	0	1.48	0	0	0.86
	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase in the traffic of the area	0.8	1.36	0	0	0.56	0	0.38	0	0	0.37	1.66	0.21	0
	2.0	3.6	0	0	1.42	0	1.18	0	0	1.18	3.64	0.54	0
Dust emission	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Toxic pollutants and substances emission to air	0.8	0	0	0.37	2.24	0	0.76	0	0	0	0	0.84	0
	10.0	0	0	4.3	28.4	0	11.8	0	0	0	0	10.8	0
Noise pollution	2.0	3.4	0	0	0	0	1.9	0	0	0	16.6	1.05	0
	0.5	0.9	0	0	0	0	0	0	0	0	7.28	0.54	0
Land vibration	0.8	0.34	0	0	0	0.4	0.76	2.5	3.32	0	0	0.21	0
	1.0	0.45	0	0	0	0.53	0.59	1.43	2.22	0	0	0.27	0
Fly rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials existed in the waste dump	0.8	0.68	1.44	1.48	1.12	0.8	0.76	0	0	0	0	0.84	1.72
	1.0	0.45	1.92	1.72	0	0.53	1.18	0	0	0	0	0.54	1.34
Waste discharge method	0.8	0.68	1.44	0.74	1.12	1.6	0.76	0	0	1.48	0	0.84	1.72
	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic employment	0	−6.8	0	0	0	0	0	0	0	0	0	−4.2	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Population control	0.4	2.72	0	0	0	1.6	0	0	0	0	1.66	1.68	0
	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued

Social and cultural development	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Instability of the established spaces	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidence	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental arrangements	−4.0	−3.4	−7.2	−2.96	−5.6	−2.0	−1.9	0	0	−7.4	−16.6	−4.2	−4.3
	−2.0	−1.8	−3.84	−3.44	−5.68	−1.06	−1.18	0	0	−4.72	−7.28	−2.16	−2.68
Light	4.0	0	0	0	0	0	0	0	0	0	0	2.1	0
	5.0	0	0	0	0	0	0	0	0	0	0	2.7	0
Total	9.75	0	4.5	9	0	15.75	13.25	3.75	10	14.5	11.75	1.5	6
	9.25	4.25	0	3.75	24.2	3.25	14.5	1.5	3.25	0	3.75	15	2.75

*For each Impacting Factor the upper value is for Construction phase. **The under value is for Operation phase.

usage and soil of the area is more than the obtained standard values. In the operation phase of this drainage tunnel, positive effects on groundwater and surface are observed. The impacts on other environmental components are lower than standards, which clearly representative of ideal conditions for this project.

The greatest impacts on the construction phase of the Eurasia tunnel will be area usage and area landscape because it is built around the tourist areas in Istanbul. Also building a tunnel under the Bosphorus Sea can cause high impact on the ecology and groundwater. This road tunnel, according to predictions by 2015 will be a main passage of many vehicles each day. Therefore, many significant impacts on air quality, ecology and economic issues are predictable, and mitigations should be devised for these problems in the exploitation phase.

Based on the acquired results, it can be said that among three case studies, Tsuen Wan drainage tunnel effected the environment in construction phase more than others, and Eurasia road tunnel will affect air quality significantly in operation phase. If monitoring indicates that concentrations are approaching the limit values, variable message signs should be used to decrease traffic in order to reduce emissions.

This is the first analysis performed for tunnels. With due attention to its usefulness and current environment, the approach could be used for all tunnels, and results in particular can be used for designing similar tunnels.

This algorithm aims at the precise use of the existing standards (domestic and international), and the interaction of several parameters; furthermore, this algorithm reduces human errors in assessments, and is an appropriate pattern to investigate the environmental effect.

6. Conclusions

Using the results of this algorithm, correct decision can be made about the environmental condition, and several parts of the tunneling site can be assessed systematically.

Reviewing the data of the three typical existing tunnels indicates that the Eurasia Road tunnel is the least destructive for the environment while the Tsuen Wan drainage tunnel is the most one in construction phase. However, the Tsuen Wan drainage tunnel is the least harmful project in the operation phase, and Eurasia Road tunnel is the most. The outlined method was originally developed for a mining and milling operation in Iran, but it can successfully be used for tunneling ventures and more general industrial activities in other countries in accordance to their environmental regulations and laws.

Note that, to the author's knowledge, this study is the first of its kind; therefore, this assessment can be done by expending more time and raised more accuracy and information on other tunnels. The provided graphs can

Table 9. Final scoring for each environmental component in Tsuen Wan Drainage Tunnel of Hong Kong in both construction and operation phases.

Impacting Factors	Environmental Components												
	Human Health and immunity	Social issues	Surface waters	Underground waters	Air quality	Area usage	Ecology	Surface constructions	Underground constructions	Area landscape	Quietness	Economical issues	Soil of the area
Changing the usage of the area	0.4*	0.34	0.72	0.74	0	1.6	0.38	0	0	1.48	0	0.84	1.72
	0.5**	0.45	0.96	0.86	0	2.12	0.59	0	0	2.36	0	1.08	2.68
Exposition of the tunneling area	0	0	0	0	0	6.4	0	0	0	11.84	6.64	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Interference with surface water	4.8	0	8.64	8.88	3.36	4.8	9.12	7.5	0	8.88	0	1.26	10.32
	0	0	0	0	0	0	0	0	0	0	0	0	0
Interference with underground water	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste waters	2.0	0	7.2	7.4	0	4.0	15.2	0	0	14.8	0	0	8.6
	0	0	0	0	0	0	0	0	0	0	0	0	0
Increase in the traffic of the area	0.8	1.36	0	0	0.56	0	0.38	0	0	0.37	1.66	0.21	0
	1.0	1.8	0	0	0.71	0	0.59	0	0	0.59	1.82	0.27	0
Dust emission	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Toxic pollutants and substances emission to air	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Noise pollution	2.0	3.4	0	0	0	0	1.9	0	0	0	16.6	1.05	0
	0.5	0.9	0	0	0	0	0	0	0	0	7.28	0.54	0
Land vibration	0.8	0.34	0	0	0	0.4	0.76	2.5	3.32	0	0	0.21	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Fly rock	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Materials existed in the waste dump	0.8	0.68	1.44	1.48	1.12	0.8	0.76	0	0	0	0	0.84	1.72
	1.0	0.45	1.92	1.72	0	0.53	1.18	0	0	0	0	0.54	1.34
Waste discharge method	0.8	0.68	1.44	0.74	1.12	1.6	0.76	0	0	1.48	0	0.84	1.72
	0	0	0	0	0	0	0	0	0	0	0	0	0
Domestic employment	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	2.25	0	0	0	0	0	0	0	0	0	2.7	0
Population control	0.4	2.72	0	0	0	1.6	0	0	0	0	1.66	1.68	0
	0	0	0	0	0	0	0	0	0	0	0	0	0

Continued

Social and cultural development	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Instability of the established spaces	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Subsidence	0	0	0	0	0	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0	0	0	0	0	0
Environmental arrangements	−2.4	−2.04	−4.32	−4.44	−2.24	−6.72	−1.14	0	0	−4.44	−9.96	−2.52	−2.58
	−2.0	−1.8	−3.84	−3.44	−0.68	−1.06	−1.18	0	0	−3.72	−7.28	−2.16	−2.68
Light	4.0	0	0	0	0	0	0	0	0	0	0	2.1	0
	5.0	0	0	0	0	0	0	0	0	0	0	2.7	0
Total	14.5	7.5	15.2	15.0	4.0	14.5	28.25	10	3.5	34.5	16.75	6.5	21.5
	6	4	−1	−0.75	0	1.5	1.25	0	0	0	2	6	1.5

*For each Impacting Factor the upper value is for Construction phase. **The under value is for Operation phase.

also offer useful ideas about environmental impacts of projects similar to those studied herein.

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